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Working conditions and musculoskeletal disorders in flight baggage handling

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Abstract

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Introduction: Baggage handling is considered to be a heavy manual handling job including biomechanical exposures suspected of increasing the risk for musculoskeletal disorders. **Aims:** To document low back pain (LBP), shoulder pain (SP), and physical and psychosocial factors in baggage handlers, and to evaluate the implementation of an ergonomic intervention aiming to increase the use of loading assist devices. **Methods:** A questionnaire was utilized to characterize pain and psychosocial work conditions in 525 baggage handlers. The postures of 55 baggage handlers during 114 shifts were measured using inclinometry, half shift video-recordings were made for subsequent task analysis, and the number of aircraft handled was registered. Associations for psychosocial and biomechanical exposures with pain were assessed using regression analyses. An ergonomic intervention was implemented and evaluated using questionnaires and repeated interviews. Feasibility, intermediate outcomes, barriers and facilitators were assessed. **Results:** The prevalence rates of reported LBP and SP were 70% and 60%, respectively. Pain interfering with work (LBP - 30% and SP - 18%) and high pain intensity (LBP - 34% and SP - 28%) were associated with poor psychosocial working conditions. Extreme postures with arms elevated >60° occurred for 6.4% of the total time, and in trunk flexion >60° for 2.1% total time. In contrast, 71% of the total time was spent in a neutral trunk posture. The 90th percentile trunk forward flexion was 34.1°. Daily shoulder pain increased in approximately one-third of all shifts and was positively associated with extreme work posture and the number of aircraft handled; this association was modified by influence and support. The intervention was delivered as planned, and dose received and satisfaction were rated as high. Motivated trainees facilitated implementation while lack of manager support, opportunities to observe and practice behaviors, follow-up activities, staff reduction, and job insecurity were barriers. **Conclusion:** The high prevalence rates of LBP and SP in baggage handlers were associated with psychosocial exposures, and daily shoulder pain was associated with higher biomechanical exposure. Barriers to implementation can be minimized by recruiting motivated trainees, securing strong organizational support, and carrying out follow-up activities.

Keywords: epidemiology, low back pain, shoulder pain, physical exposures, psychosocial exposures, inclinometry, implementation, process evaluation

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To my family

List of Papers

This thesis is based on the following papers, which are referred to in the text by their Roman numerals.

I Bergsten, E.L., Mathiassen S.E., Vingård, E. (2015) Psychosocial work factors and musculoskeletal pain: a cross sectional study among Swedish flight baggage handlers. *BioMed Research International,* 2015:798042

II Wahlström, J., Bergsten, E.L., Trask, C., Mathiassen, S.E., Jackson, J., Forsman, M. (2016) Full-shift trunk and upper arm postures and movements among aircraft baggage handlers. *The Annals of Occupational Hygiene*, 54: 584-94

III Bergsten, E.L., Mathiassen, S.E., Kwak, L., Vingård, E. Daily shoulder pain among flight baggage handlers and its association with arm postures and work tasks on the same day. *Submitted for publication January 2017.*

IV Bergsten, E.L., Mathiassen, S.E., Larsson, J., Kwak, L. Implementation of an ergonomics intervention in a Swedish flight baggage handling company – a process evaluation. *Submitted for publication February 2017.*

Contents

Abbreviations

BMI	Body Mass Index
CI	Confidence interval
COPSOQ	Copenhagen Psychosocial Questionnaire
FP	Forward projection
FuQ	Follow-up questionnaire
GEE	Generalized Estimating Equations
HR	Hazard ratio
IATA	International Air Transport Association
INC	Inclinometry
ISO	International Standardization Organization
KP	Key person
LBP	Low back pain
LP	Lateral projection
MSD	Musculoskeletal disorders
NMQ	Standardized Nordic Questionnaire
OHS	Occupational Health and Safety
PINT	High pain intensity
PIW	Pain interfering with work
SD	Standard deviation
SMS	Short message service
SOI	Safety officers and instructors
SP	Shoulder pain
TYA	The Vocational Training and Working Environment Council, (Transportfackens Yrkes- och Arbetsmiljönämnd)
ULD	Unit load device

Introduction

The Swedish Transport Workers´ Union has noted increases in the frequency of work-related incidents, accidents and sickness due to musculoskeletal disorders reported by baggage handlers. Together with the Vocational Training and Working Environment Council (Transportfackens Yrkes- och Arbetsmiljönämnd – TYA - a council formed jointly by the transport union and the association of aviation industry employers), they conducted a project from 2010-2012 entitled "Skadefria cargo- och flygplanslastare" aiming to document work environment conditions as a basis for improving health and preventing musculoskeletal disorders. In Sweden baggage handlers at larger airports are employed by handling companies that operate as contractors at the larger airports, otherwise directly by the airport. Six Swedish airports and fourteen handling companies were included in the TYA project.

The work included in this thesis represents a major contribution to this project and involved quantifying the prevalence of musculoskeletal disorders (MSDs) and describing work-related physical and psychosocial exposures of potential importance in connection with low back and shoulder pain among flight baggage handlers. Furthermore, this thesis evaluates the implementation of an occupational intervention implemented by TYA, including the assessment of barriers and key facilitators of importance for a successful implementation.

Background

Flight baggage handling

The first commercial airline flight on January 1, 1914, carried only one passenger, while today, a hundred years later, on this same date, 8.5 million passengers flew on approximately 100 000 passenger flights operated by almost 1,400 airlines with a total fleet of 25,000 aircraft serving 4,000 airports[28]. If, approximately, every fourth passenger checks in a single 10 kg bag (a rather conservative assumption), 43 million kg of luggage would have to be loaded and unloaded every day. Sweden currently has 41 airports with about 1,400 baggage handlers and during January of 2016, 2.6 million passengers flew from the ten largest Swedish airports.

These baggage handlers typically work either in baggage sorting or at the ramp, i.e. the area around the aircraft. In the sorting area, baggage handlers load and unload checked-in baggage onto carts or Unit Load Devices (i.e., containers which are subsequently loaded onto the aircraft). In addition, these workers use trucks to transport carts and ULDs to and from the ramp. At the outdoor ramp near the aircraft they sort, load and unload baggage, cargo and mail employing conveyor belts and, for ULDs, a 'highloader' vehicle. The other tasks performed by baggage handlers include towing aircraft to and from the gates with a pushback vehicle, attaching auxiliary power cables, placing brake bumpers behind the wheels, pulling pylons and stairs into place around the parked aircraft, de-icing and refueling. At smaller airports baggage handlers may provide even more diverse services, e.g., snow clearance and fire protection.

Baggage handling involves similar tasks at all larger airports and is, according to previous studies and "grey literature", characterized by heavy lifting, pushing and pulling on the ground, and work in constrained and awkward postures, such as sitting, stooping, kneeling and even lying down [19, 94]. The occurrence of musculoskeletal disorders (MSDs) has been considered, but scientific documentation is sparse and for the most part more than twenty years old [19, 45, 53, 86, 89, 94, 95, 101]. Of these studies, one documented a high prevalence of MSDs in the back, knees and shoulders [95]. A more recent investigation on Danish baggage handlers reported one year prevalence of 33% for LBP and 25% for SP [11].

Among the attempts to characterize baggage handling tasks, some have been experimental, [45, 89, 94, 95], and several have evaluated interventions, including changes in working technique [45, 53], and a use of a conveyor belt [101] or weightlifting belt to prevent pain [86]. However, neither the nature of and variation in trunk and arm postures and movements during work shifts nor associations between work exposures during a shift and "short term", daily pain have been examined. Furthermore, no studies addressing psychosocial work factors in this context appear to have been performed.

Although based on relatively little scientific evidence, working techniques [19, 53, 94], years of employment and cumulative heavy lifting [11, 102] have been proposed risk factors associated with baggage handling. Loading and stowing bags in a narrow body aircraft was rated by baggage handlers and safety officers as the risk factor most closely associated with LBP [19]. In one experimental investigation, greater bag weight and stowing height from kneeling position increased spinal loading [94]; while in another, information about bag weight (bag tags) and an altered stowing procedure reduced cumulative spinal loading and trunk muscle activity [53].

According to company and union representatives, many different organizational factors may influence the workload of an individual baggage handler, including air traffic intensity, the number and type of aircraft assigned during a shift, the tasks assigned in connection with loading and/or unloading, the quantity and weight of checked baggage, and weather conditions on the ramp. Baggage handling companies, which as contractors at the larger airports, rent their operating facilities and provide services through various service level agreements, have only limited possibilities to promote technical or organizational interventions related to the work environment facilities, certain of the loading devices and in particular, the aircraft served.

Low back and shoulder pain

The frequency of musculoskeletal pain, a common problem among the general global population, varies between studies. The incidence of low back pain (LBP) at some point in life ranges from 51-84% [69], with corresponding values 7-67% [64] in the case of shoulder pain (SP). The corresponding annual prevalence range from 0.8-82.5% [40] and 5-47% [64]. These wide ranges reflect factors such as differing definitions of pain severity, duration and associated disability.

Low back and shoulder disorders among workers are a major cause of morbidity at work, resulting in sick leave and compensation claims. Among the working population of Sweden, approximately half of all such claims are related to musculoskeletal disorders and about 25% of female and 20% of male workers reported work related musculoskeletal disorders last year [90] and both environmental and personal factors influence the incidence and the course of this disorder. According to Punnett and colleagues [84], 37% of world-wide LBP was occupational.

Work-related musculoskeletal pain

The World Health Organization expert committee describes as multifactorial, "work-related diseases" to which the occupational environment and the performance of work contribute significantly [29 (p.17-18)]. It is assumed that loading of tissue structures associated with repetitious or uncomfortable work, movements and/or postures and/or inadequate recovery time, may give rise to musculoskeletal disorders or pain (WMSD). Normally, tissues adapt to stress, but if the mechanical overload exceeds its physiological tolerance, e.g., due to excessive, sustained and/or repetitive exertion, pathological changes may occur with outflow of metabolites which activates pain receptors in the muscle. Another mechanism proposed involves local ischemia, with resulting accumulation of metabolites in the muscle [79 (p.152)].

However, it seems unlikely that a single physiological process can explain the development of pain, which appears to be multifactorial. The role of psychosocial factors in this context is not yet fully understood, since mechanisms that might link psychosocial factors to MSDs remain unknown. Certain overlapping models have been proposed.

The gate control theory of pain presented by Melzack and Wall in 1965 [72] provided new insights into the transmission and alleviation of pain. This theory proposed that by stimulating of non-nociceptive afferent nerve fibers (e.g., stimulation of mechanoreceptors with massage) a gating mechanism located in the dorsal horn of the spinal cord regulates incoming pain signals before impulses are then sent to the brain. Another common model is the "Cinderellea hypothesis", suggesting that overuse of low-threshold motor units that are constantly active during prolonged mental activity or low-level physical activity can lead to metabolic disturbances, exhausted and damaged muscle fibers, and the development of pain [71]. When activation of the neural, neuroendochrine and immune systems by stressful challenges, so-called allostatic load, is not turned off normally, health problems may also develop [70].

Concerning ergonomic interventions designed to improve the work environment and reduce physical load, Lundberg and co-workers [65] suggest that the lack of rest and recovery from physical and mental stress may be a more important health problem than the physical work load itself. However, if low-threshold motor units are activated by both mental and physical effort, recovery alone may not reduce the risk for MSDs [65].

Work-related exposures

Physical factors

Several systematic reviews indicate that heavy lifting, repetitive work [16, 26] and working in awkward postures [16, 37, 85, 91, 116] elevate the risk for developing LBP. For example this risk has been proposed to be increased by trunk flexion of 60° or more for longer than 5% of the working day was suggested [37].

Physical risk factors for developing shoulder disorders identified previously include heavy work load, working with the hands above shoulder level, pushing and pulling [34, 59, 68, 108, 111], repetitive movements [2, 59, 108, 111], and vibration [57, 68, 90, 108, 111]. Roquelaure and colleagues (2011) found that arm abduction, by more than 90° for men and 60° for women for two hours or more per day increased the risk of shoulder disorders (rotator cuff syndrome) [88]. A Swedish report based on technical measurements, recommends elevating the arm more than 60° for at most 10% of working time [31].

The biopsychosocial model

When physical conditions alone cannot explain the development of MSDs, psychological and social attributes may be involved. The biopsychosocial model described by Engel in 1977 [23] presents pain from a multidimensional perspective that takes interaction between biological, psychological and social factors and/or physical load into consideration [14, 18, 71]. Increased muscle tension may give rise to biomechanical stress [14, 71, 106], increased levels of muscle metabolites, inflammatory alterations, and subsequent muscle pain [100]. For example, negative feelings about work may lead to adverse psychological and physiological strain, with muscle tension or elevated levels of catecholamines and production of cortisol, as well as poor working methods, the use of excessive force to accomplish a task and failure to rest [29 (p.8)].

Psychosocial factors

The importance of work-related psychosocial factors in the development and/or aggravation of low back and shoulder pain has been highlighted by epidemiological studies [16, 35] suggesting that high demands [38] and poor social support increase the risk for LBP, sick leave, restricted activity and failure to return to work due to LBP [35, 38, 124]. Furthermore, a review by Linton [62] concluded that low job satisfaction, stress and the belief that one´s work is dangerous in terms of back pain and disability are also associated with LBP.

A relationship between work-related psychosocial factors and shoulder symptoms has been indicated by several systematic reviews [13, 35, 111], but the results are inconsistent [108]. Most of the studies reviewed involved a cross-sectional design [13, 108, 111], but more recent reviews addressing only longitudinal studies suggest that high work demands, low control, perceived stress [13, 35, 57], low social support, low authority to make decisions [35, 57] and low influence in general [57] are associated with shoulder symptoms.

In contrast, a Swedish systematic review provides no support for associations between shoulder pain and high work demands, and lack of support and control. The main reason for such inconsistencies are methodological, including a lack of longitudinal designs and of well-defined exposures and outcomes that can be measured objectively [90].

Measuring pain

Epidemiological characterization of LBP and SP is difficult and the findings vary greatly, probably due to many factors such as different definitions of pain and periods of prevalence [41, 69]. Indeed, most studies of this nature have not specified the minimum duration of pain considered; the period of prevalence most commonly, prevalence at one point in time, followed by one year and one month; and whether the pain limited activity [41].

Self-rated prevalence of pain, pain intensity and pain interfering with work can be assessed with questionnaires and other forms of self-reported information, by personal interview or clinical examination. Although clinical examination might be more specific [44], questionnaires are often used in epidemiological studies for reasons of feasibility and cost. In this context, mobile phone and text messages (SMS) are being used more and more frequently and have proven to be a cheap and user-friendly alternative [7] that yields high response rates [7, 52].

Pain intensity can be assessed on numerical or verbal scales or with pain-faces, all procedures commonly applied in both clinical and research settings and shown to demonstrate good validity and sensitivity [24, 36].

When evaluating cross-sectional questionnaire data, (e.g., retrospectively reported pain) potential recall bias must be taken into consideration. However, recall of pain intensity and interference with activities for at least three months has been shown to exhibit acceptable validity [123]. At the same time, self-reported prevalence of pain is greater than the prevalence confirmed by clinical examination [44] associations between psychosocial work factors and self-rated pain are stronger than with pain diagnosed by physical examination [17].

Another limitation in this connection involves where and when data are collected; attribution bias may occur if workers are required to answer the questionnaire at work rather than outside work [9]. Workers who believe occupational factors may lead to pain frequently consider their exposure to such factors to be greater and attribute their pain more strongly to their work [17].

On the other hand, conducting studies in occupational settings may give rise to a so-called "healthy worker survivor effect", i.e., those participating are currently employed and may be healthier than those who are sick and not present [6].

Measuring exposure

Physical factors

The impact of the amplitude, frequency and duration of the exposure to physical factors on the human body or parts thereof [122] is often assessed with different instruments and methods with varying degrees of precision and accuracy; self-reports, observations and direct technical measurements [82, 119]. The limitations associated with self-reporting of postures and movements in questionnaires, diaries or interviews include recall bias and poor ability to quantify duration and frequency in detail [119], e.g., overestimation of duration [99, 105]. Although a structured interview is more reliable and valid than a self-administered questionnaire [120], the latter are often used in larger epidemiological studies since they can provide information about many different types of exposure and are relatively inexpensive.

The major limitation associated with observational studies involving approaches such as filming and/or checklists is the ability of the investigator to interpret what is observed [97]. For example, in comparison to an inclinometry, observers found it difficult to assess postural angels with precision, although extreme postures were evaluated well [121].

With regard to objectivity and precision, measuring with technical instruments is preferable to self-reported and observed postures [119], and several such instruments are available. A triaxial accelerometer, i.e., an inclinometer that measures the angle of a body part in relation to the line of gravity, is commonly employed. In general, inclinometers are frequently utilized in epidemiological field studies and have been found to be safe, light weight and easy to use for both researchers and workers moving inside and outside, changing clothes and performing various tasks [12, 30]. Data are stored in a device worn by the worker or in the inclinometer itself and working postures and movements can be recorded for prolonged periods [30].

Psychosocial factors

Among the models applied to the assessment of psychosocial stress factors in the working environment and their impact on worker health [96], the most commonly used is the Demand-Control Model proposed by Karasek (1979) [48], later expanded to include a social support dimension [49]. This model postulates that great psychological demands (time pressure, mentally demanding tasks, etc.), together with lack of control and influence over one´s working conditions (i.e., low decision latitude) leads to a high level of work strain. Among the variety of instruments employed in this context, the Job Content Questionnaire is designed to assess psychological demands, ability to make decisions, social support, physical demands and job insecurity [47]. The Effort-Reward-Imbalance (ERI) proposed by Siegrist (1996) [93] emphasizes that a lack of mutuality between work effort and rewards such as income, occupational status, career opportunities, etc., results in emotional stress. The General Nordic Questionnaire (QPS Nordic) [125] and the Copenhagen Psychosocial Questionnaire (COPSOQ) [54] cover a broad range of psychosocial factors with a variety of scales.

Ergonomic interventions designed to prevent MSDs

Many ergonomic interventions designed to prevent MSDs among the working population include behavioral, organizational and/or psychosocial elements [55]. Although many organizations invest considerable resources in interventions designed to improve the work environment and prevent health problems among their employees, it is not always clear how successful these are, and evidence for the effectiveness of ergonomic interventions is inconsistent [51, 109, 110, 115].

Assessment of ergonomic interventions often focus solely on the effect outcomes, such as exposure and MSDs, often being designed with little consideration of theories concerning effective change, and rarely incorporating systematic assessment of barriers and facilitators to the implementation process [73, 76, 78, 117, 118]. A better understanding of the implementation process can increase the likelihood of success [109] and facilitate analysis of whether the intervention worked and why [61, 75, 78].

Implementation of interventions

The effectiveness of ergonomic interventions also depends on the extent to which the intended intervention is effective in reducing MSDs, and the extent to which these are actually adopted by the organization and individual workers [55, 114]. Social and behavioral interventions in multiple company locations and involving different groups of employees are complex and require even more detailed evaluation. This increases the need of ensuring to what extent the intervention has actually been equally implemented and with regard to the outcome, what barriers and facilitators may have influenced the implementation and in what direction. Moreover, such evaluation can help policy makers and practitioners decide how to replicate or modify the intervention [74].

In early 2000, interventions began to be evaluated more often, although published reports remain sparse [61], and different frameworks and guidelines for evaluating an implementation process have been proposed [61, 74, 77]. However, a systematic review has indicated that the quality of such evaluations is in general average or poor, e.g., due to the lack of systematic assessment of barriers and facilitators through questionnaires or interviews, such barriers and facilitators have most often been examined solely on the basis of the experience of the researchers and, consensus concerning the definition of process components is required [117].

Aims of the thesis

The primary aim of this thesis was to document physical and psychosocial exposures and associations with low back and shoulder pain among flight baggage handlers. The secondary aim was to evaluate implementation of a related work environment intervention. The specific aims were as follows:

I to document low back and shoulder pain, and determine the extent to which psychosocial factors are associated with pain intensity and pain interfering with work.

II to quantify full shift trunk and upper arm postural exposures and determine the extent to which exposures differs between baggage handlers working on the ramp and in the sorting areas.

III to examine the development of self-reported shoulder pain during a single work shift and subsequently, the extent to which psychosocial factors and biomechanical exposure during the same shift can explain the pain.

IV to evaluate the implementation process of an ergonomic intervention aimed at increasing the use of loading assist devices among flight baggage handlers.

Methods

Design and participants

Paper I was a cross-sectional study based on a questionnaire distributed to 806 Swedish flight baggage handlers employed either by a handling company or directly by the airport. This questionnaire covered demographic factors (age, gender, height, weight, work experience) and included questions concerning musculoskeletal disorders, psychosocial work factors, physical workload and general health.

Paper II was based on assessment of trunk and upper arm elevation by 27 baggage handlers selected randomly, (16 ramp workers and 11 sort workers, (Table 1)) throughout three full work shifts using inclinometers. The cumulative distribution of postures and movements, extreme postures, rest and recovery, and variation of exposure were described and analysed [67].

Paper III was based in part on the data collected in papers I and II. In addition to the inclination measurements and video recordings of the 27 subjects in study II, an additional 28 subjects in another five smaller airports, were examined in the same manner, giving a total of 55 subjects (Table 1). At these smaller airports, data were collected for one shift only, for a total of 114 shifts measured (Table 1). Potential association between biomechanical and psychosocial work factors and daily shoulder pain were assessed. Independent factors likely to demonstrate such associations on the basis of previous reports and reasonable assumptions were selected as independent variables; work in extreme arm postures [87], the duration of neutral arm postures, the number of aircraft handled (as a proxy for strenuous work), influence at work and support from colleagues [57]. The difference between shoulder pain rated before and after work served as the dependent variable.

Table 1. The number of baggage handlers working on the ramp or in the sorting area (sort)) and shifts video recorded (VR) and assessed with respect to upper arm inclination (INC) at six airports.

	INC Subjects n (ramp/sort)	INC Shifts n (ramp/sort)	Video Subjects n (all ramp)
Airport 1	27 (16/11)	86 (54/32)	5
Airport 2	6 (6/0)	6 (6/0)	6
Airport 3	5 (5/0)	5 (5/0)	5
Airport 4	6 (6/0)	6 (6/0)	4
Airport 5	6 (6/0)	6 (6/0)	5
Airport 6	5 (5/0)	5 (5/0)	4
Total	55 (44/11)	114 (82/32)	29

Paper IV describes the evaluation of an intervention, an ergonomic training program, including barriers and facilitators to the implementation. This program was designed to reduce and prevent MSDs by promoting the use of loading assist devices through improvement of work skills and confidence in the use of the devices, as well as of communication between workers. An expert organization conducted this training program at the work site during working hours. The program covered Ergonomics (when, why and how to use devices) and Human Factors at work (HF) (work rules, norms and how to communicate). Of the 93 eligible baggage handlers with key roles in the company (safety officer, coordinator, instructor, manager) 50 participated in at least one of the two days of training (Table 2). Telephone interviews during implementation, course evaluations and a web-based questionnaire (FuQ) four months later were carried out.

Table 2. Eligible key persons and participants in the Ergonomics and Human Factors parts of the training program.

Role in the company	Eligible	Participants in Ergonomics		Participants in Human Factors		Participants in both parts	
	n	*n*	*% of eligible*	*n*	*% of eligible*	*n*	*% of eligible*
Safety officer	16	12	75	11	69	11	69
Coordinator	42	11	26	11	26	8	19
Instructor	26	13	50	9	35	7	27
Manager	9	7	77	4	44	2	22
Total	93	43	46	35	38	28	30

All subjects provided their written informed consent prior to participation and these studies were pre-approved by the Regional Ethical Review Board in Uppsala, Sweden.

Data collection and measurements

The questionnaire (Studies I and III)

In Study I, the questionnaire administered at the workplace by a member of our research team required approximately 20-30 minutes to complete and was collected on the same occasion or could be returned in a sealed envelope by mail. We visited all of the participating companies and airports involved and the baggage handlers were approached in person and given information concerning the study. Repeated visits were required to cover the different work shifts and to contact participants a second or third time if they had not yet submitted their questionnaire. We did not have access to telephone numbers or addresses for reminders.

The one-year prevalence of LBP, SP and pain that interfered with work (PIW) was measured with the Standardized Nordic Questionnaire [20, 56]. Pain intensity was reported on a 10-grade VAS-scale ranging from "no pain" to "very very high (almost maximal)". The workload on the low back and shoulders in connection with different tasks was rated using the question "how do you perceive the physical load in task xx", with answers on a six-grade scale ranging from "not at all" to "to a large extent". General health was rated on the basis of the single question "In general, how would you rate your health?".

Psychosocial factors were assessed with two domains of the latest edition of the medium-length Copenhagen Psychosocial Questionnaire (COPSOQ) [54]: *Work organization and job content* (including five factors; influence at work, possibilities for development, variation, meaning of work, commitment to the workplace) and *Interpersonal relations and leadership* (including eight factors; predictability, recognition, role clarity, role conflicts, quality of leadership, social support from colleagues, support from supervisors, social community at work). Each of these factors, was addressed with 2-5 questions giving a total of 42 questions altogether.

Questions concerning six of these factors (influence at work, variation, commitment to the workplace, social support from colleagues, social support from supervisors and social community at work) were answered on a five-grade scale ranging from "always" to "never/hardly ever", whereas for the other seven factors (possibilities for development, meaning of work, predictability, recognition, role clarity, role conflicts and quality of leadership) the five-step scale ranged from “to a large extent” to “to a very small extent”. The answers were assigned a value of 0, 25, 50, 75 or 100 and an overall mean score calculated according to Pejtersen et al. [81]. In general, a higher mean score indicates a more positive work environment, with the exception of role conflict, where the opposite is true.

Measurement of postural angles (Studies II and III)

Five researchers trained in the use of inclinometers collected data throughout the full morning, afternoon and night shifts, with instrumentation being set up prior to each shift.

VitaMove tri-axial accelerometer Inclinometers (INCs) (2 M Engineering, Veldhoven, the Netherlands) were used to measure trunk and arm angles. These INCs were attached over the flattest lateral portion of the deltoid muscle of each of the upper arms, with the upper edge at or below the level of the superior aspect of the acromion process and with the long axes aligned with the humerus when the arm was at 0^{o} [104] (i.e., leaning to the side with the arm hanging while holding a 1-kg dumbbell [32, 50, 107]. To assess inclination of the trunk, each participant wore a customized harness containing an INC mounted between the medial borders of the scapulae and with the upper edge aligned with the superior borders of the scapulaes. No trunk inclination was recorded while standing upright.

Video recording and diaries (Study III)

Workers participating in the postural measurements were video recorded continuously during the first or second half of their shift and work task analysis were conducted.

During the shifts assessed, the baggage handlers registred the number of aircraft loadings and unloadings they were involved in, in a paper diary.

Prior to and immediately after their work shift, the participants rated their shoulder pain on a 0-100 mm VAS scale ranging from “no pain” to “worst pain imaginable”.

Evaluation of the process and intermediate outcome (Study IV)

Immediately after the training program, the participants filled out a course evaluation rating engagement, communication techniques learned, the utility of new skills, overall satisfaction and satisfaction with time allocated, as well as the relevance of the training.

Four months later they rated intermediate outcomes in the web-based FuQ, i.e., how they perceived their *skills*, their *confidence* in discussing the use of loading devices at work, how often they used these devices, how often they taught colleagues to use them, and how much feedback they gave colleagues regarding their work *behavior*.

Following the recommendations of Linnan and Steckler [61], this data collection and evaluation of the implementation process focused on the following six items; i.e. *recruitment, context, reach, dose delivered, dose received and satisfaction.*

Recruitment and *Context* - information regarding the process of recruitment of participants and the organizational context was collected by the individual responsible for Occupational Health and Safety (OHS) at the company and by a representative from the expert organization conducting the intervention. *Reach,* defined as the proportion of the intended participants who actually attended the program, was provided by company data, as was the *dose delivered*, i.e., the extent to which the intended training was delivered as planned, measured in hours and component parts (materials and exercises performed). *Dose received*, the extent to which the training was received by the target group, was rated by having the participants indicate on a four-point scale (”not at all” to ”to a very large extent”) the extent to which they were engaged in the training, considered the knowledge to be useful, would get use of this new knowledge, would consistently practice their new skills and would be capable of and have the opportunity to transfer this new knowledge to colleagues. Participants in the HF training only rated the extent to which they were engaged and had learned useful communication techniques, as well as the likelihood that they would use these new skills. *Satisfaction* was rated on the basis of the time allocated to training on a four-point scale (”too little” to ”way too much”) and on the relevance of the training contents (”not at all” to ”to a very large extent”). Overall satisfaction was rated on a ten-point scale ranging from 0 (“extremely disappointed”) to 10 (“extremely satisfied”) in connection with the four-month follow-up web questionnaire.

Specific barriers and facilitators that influence the implementation were assessed with respect to: *trainee characteristics*, *training design* and *work environment,* as identified by Grossman and Salas [27] and in accordance with the model of Baldwin and Ford [8]. Data were collected both with the FuQ and by repeated semi-structured, 15-20 minute telephone interviews (Table 3) with 18 randomly selected KPs, 6 safety officers and 6 instructors six months after training and with 6 managers nine months after the training. A standardized protocol focussing on all ten components of barriers and facilitators was employed (Table 3). Moreover, a total of six KPs, (3 safety officers and 3 instructors), acted as ”observers”, providing monthly follow-up information (for 4-7 months after the training) to a member of our research team concerning organisational barriers and facilitators (e.g., factors related to schedules, staffing, loading devices, vehicles and facilities).

Table 3. Components in the process and outcome evaluation and methods used to retrieve information in the present study.

Components	Explanation	Source of data
Process items		
Recruitment	Procedures used to recruit participants to the training program.	Company
Context	Organisational factors that may influence program implementation.	Interview
Reach	Proportion of intended participants, who actually attended.	Company
Dose delivered	Number of training hours and components delivered.	Course evaluation Company
Dose received	Extent to which the participants were actively engaged, interacted and used the materials and resources provided.	Course evaluation Company
Satisfaction	Satisfaction with the training content and delivery in terms of time, relevance and usefulness.	Course evaluation
Barriers & Facilitators		
Trainee characteristics		
Self-efficacy	The participants' judgment of their own competence to perform a task.	FuQ, interview
Motivation	Motivation to learn and transfer knowledge.	FuQ, interview
Perceived utility of training	Perception of whether the training is useful and valuable	FuQ, interview
Training design		
Behavioral modeling	Observing and practicing target behaviors.	FuQ, interview
Error management	Practicing knowledge and skills by making errors and receiving appropriate feedback.	Interview
Realistic training environment	Learning and practicing in the work environment.	Interview
Work environment		
Transfer climate	Extent to which the skills learned are applied and feedback on performance received.	FuQ, interview
Support	Supervisor and peer support including communication of goals and feedback regarding desired and acceptable performance.	FuQ, interview
Opportunity to perform	Opportunities to utilize new skills, e.g., by modifying working conditions.	FuQ, interview
Follow-up	Additional learning opportunities after the training period.	Interview

Intermediate effects	FuQ
Skill	FuQ
Confidence	FuQ
Behavior	

Data processing and analysis

Paper I

High pain intensity (PINT) was defined as a rating of 5 or higher in accordance with the findings by Andersen and colleagues [3] that subjects with such a high rating were at higher risk for long-term sickness absence. Pain that interfered with work (PIW) was rated dichotomously “yes” or “no”. Descriptive data on the one-year prevalence of LBP and SP, as well as different expressions of pain (such as PINT and PIW) were tabulated.

Each of the 13 psychosocial factors was analyzed both individually and grouped into one of the domains, *Work organization and job content* or *Interpersonal relations and leadership*. For analysis of potential associations between self-reported psychosocial work-related factors and pain, Cox proportional hazard regression with constant time at risk was used, with PINT and PIW for both the low back and shoulders as the dependent and psychosocial factors at work as the independent variables. All models were adjusted for age, BMI, general health and physical work load. Hazard Ratios (HR) with 95% confidence intervals (95% CI), which can be interpreted as estimates of prevalence ratios [10], were determined. All analyses were performed with the SAS 9.3 software (SAS Institute Inc.)

Paper II

Inclinometer measurements were sampled synchronously at 32 Hz and stored. Trunk inclination was computed in the forward (FP) (i.e., trunk flexion in the sagittal plane) and lateral (sideways) projection (LP) (i.e., lateral flexion in the frontal plane). The angle of the upper arm was calculated relative to the vertical plane. The raw inclinometer data were subsequently down-sampled to 20 Hz and processed using software developed at the Department of Occupational and Environmental Medicine, Lund University, Sweden [30, 33].

As suggested by Kazmierczak et al. [50], postures were grouped as cumulative distribution percentiles (10^{th}, 50^{th}, 90^{th} and 99^{th}). The overall duration of extreme postures (percentage time with the back flexed at $>60^{o}$ or the arms elevated $>60^{o}$), time at rest (percentage time with trunk flexion or the arms elevated $< 20^{o}$ and movement velocity $< 5^{o}s^{-1}$), periods of ‘micro-recovery’ (the number of separate periods (>3 s) per minute in a neutral posture (< 20°)) and proportion of time spent working at high (>$90^{o}s^{-1}$) or low (<$5^{o}s^{-1}$) angular velocity for at least three consecutive seconds were calculated. The difference between the 90th and 10th posture percentiles served as a measure of the variation in exposure, percentile range [67].

Daily posture exposures were measured for each worker and averaged across the days of measurement and a group mean calculated. Intra-individual (between days) and inter-individual variances (between subjects) were estimated. Exposure variability was expressed in terms of the standard deviation (SD) between subjects (SD_{BS}) and between days within subject (SD_{BD}). A Wilcoxon rank-sum test was used to compare trunk and upper arm postures and velocity for baggage handlers working on the ramp versus in the sorting area. All statistical analyses were performed with the statistical JMP software, version 10.0 (SAS Institute Inc., NC, USA) and statistical significance was assumed for $p \leq 0.05$.

Paper III

In Study III, the independent variables *time in extreme* arm posture, *time in neutral* arm posture, and number of *aircraft handled* were processed as in study II, while *influence* and *support* were analysed as in study I.

Analysis of work tasks

The variable *aircraft handled* were determined and summarized with a customized computer video analysis tool, ATM 3.0 [25] . The activities performed were categorized as ‘ramp inside’ or ‘ramp outside’, with three activities; on their way out/waiting (walking around waiting for colleagues, getting dressed), recovery (eating, drinking coffee, socialising, watching TV, playing cards), and administration belonging to the former and five; driving vehicles, manually pushing/pulling baggage carts, arrival/departure (directing aircrafts, placing auxiliary power cables, brake bumpers and stairs into place), loading/unloading aircraft on the ground and inside compartment and garage work (in smaller airports) to the latter. The characteristics of ‘ramp outside’ activities were used to describe the contents of the variable *aircraft handled*.

Descriptive data on the participants, level of exposure and ratings of pain across shifts were presented as means and SD. Potential differences between ramp and sort workers with respect to age and work experience were examined using t-tests.

Potential associations between the outcome *daily pain* and the exposure variables *aircraft handled, time in extreme* shoulder postures, *time in neutral* shoulder postures*, influence* and *support* were analysed by linear regression.

Since repeated measurements on some of the workers were included, Generalized Estimating Equations (GEE) were applied to account for within-subject correlations. First, univariate associations between *daily pain* intensity and each of the variables age, shoulder pain before the shift, number of *aircraft handled, time in extreme* posture*, time in neutral* posture*, influence* and *support* were determined independently for the right and left upper arm for use in the analyses of right and left shoulder pain, respectively. Seniority was strongly correlated with age and was, therefore, not analysed separately.

Secondly, we determined the association between *daily pain* intensity and the biomechanical factors found to be significant in the univariate analyses, i.e., number of *aircraft handled* and *time in extreme* posture for ramp workers and *time in extreme* posture for sort workers. Both models also included age and prior shoulder pain as potential confounders. In a final GEE model, we included all variables assumed to be associated with *daily pain* intensity in order to assess the combined effects of biomechanical and psychosocial factors, adjusting for confounding. All analyses were performed with the SPSS v. 22 software (SPSS Inc, Chicago, IL).

Paper IV

The process items *recruitment, context, reach, dose delivered, dose received* and *satisfaction*, as well as barriers and facilitators were described (Table 3).

The telephone interviews were transcribed and quotations describing the ten barriers and facilitators retrieved and organized by a member of the research team. A second researcher, familiar with the training program and the implementation process, also evaluated the transcribed interviews, extracting key quotations concerning barriers and facilitators. These two researchers first worked independently and then met to reach consensus concerning interpretation of the major findings.

In the case of the intermediate outcomes *skills, confidence* and *behaviour*, differences between ratings before and after the intervention were tested for a systematic change using the Wilcoxon Signed Rank test, with estimation of the non-parametric 95% confidence interval for the median differences by the Hodges-Lehmann procedure. Differences in the ratings by the different KP groups were analyzed using the Kruskal-Wallis test. Statistical analyses were performed in the SPSS v. 22 software (SPSS Inc, Chicago, IL) and to compensate for multiple testing, the level of significance was set at $p<0.01$.

Results

Prevalence of pain (Paper I)

The response rate in Study I was 65%; and of the baggage handlers who answered the questionnaire, 98% were men and 2% were women. The one-year prevalence of LBP and SP were 70% and 60% respectively, with nearly half (45%) of our subjects reporting that they had experienced both. LBP interfered with work (30%) more often than shoulder pain (18%) and LBP intensity was high (30%) more often than SP intensity (28%).

Work-related psychosocial work factors (Paper I)

The scores for work-related psychosocial factors indicated greatest dissatisfaction with the *quality of leadership* and (lack of) *influence at work*, while the baggage handlers were most satisfied with the social community at work. This pattern was the same for all ratings of pain intensity and interference with work. At the same time baggage handlers reporting no pain (n=79) expressed higher satisfaction with their psychosocial working conditions.

Regression analyses adjusted for age, BMI, general health and physical workload revealed that a low rating (dissatisfaction) in the domain *Work organization and job content* was significantly associated with PIW in both LBP and SP (Adjusted Hazard Ratios 3.65 (95% CI 1.67-7.99) and 2.68 (1.09-6.61)); while low rating in the domain *Interpersonal relations and leadership* was significantly associated with LBP PIW (HR 2.18 (1.06-4.49)) and with PINT LBP and SP (HR 1.95 (1.05-3.65) and 2.11 (1.08-4.12)).

Workers with a more negative opinion about their work organization and job content were more likely to experience pain that interfered with work (PIW) (Table 4) and workers with a more negative attitude concerning relationships at work were more likely to experience more intense pain (PINT) (Table 5).

Table 4. Hazard ratios (HR) with 95% confidence intervals for associations of psychosocial factors with pain interfering with work (PIW) in the low back (LBP) and shoulder (SP) during the preceding year. All analyses were adjusted for age, BMI, general health and physical work load. Significant HRs marked in boldface.

	LBP PIW		SP PIW	
	HR	**95%CI**	**HR**	**95%CI**
Work organization, job content				
Influence at work	1.60	0.83-3.09	2.12	0.98-4.57
Possibilities for development	**2.86**	**1.32-6.18**	**2.63**	**1.06-6.51**
Variation	**2.31**	**1.08-4.94**	1.33	0.55-3.20
Meaning of work	**2.76**	**1.35-5.61**	2.06	0.86-4.91
Commitment to the workplace	**2.39**	**1.15-4.95**	1.44	0.63-3.29
Interpersonal relations				
Predictability	1.94	0.94-3.98	1.44	0.62-3.37
Recognition	**2.67**	**1.33-5.35**	**2.57**	**1.11-5.95**
Role clarity	1.61	0.76-3.40	1.05	0.45-2.46
Role conflicts	1.25	0.58-2.72	2.08	0.81-5.30
Quality of leadership	1.77	0.82-3.82	1.22	0.51-2.94
Social support from colleagues	**2.48**	**1.16-5.29**	**4.06**	**1.55-10.65**
Social support from supervisors	**2.22**	**1.08-4.58**	1.33	0.60-2.95
Social community at work	0.85	0.42-1.73	1.47	0.67-3.25
Work organization	**3.65**	**1.67-7.99**	**2.68**	**1.09-6.61**
Interpersonal relations	**2.18**	**1.06-4.49**	2.09	0.88-4.96

Table 5. Hazard ratios (HR) with 95% CI for associations of psychosocial factors with high intensity pain (PINT) in the low back (LBP) and shoulder (SP) during the preceding year. All analyses were adjusted for age, BMI, general health and physical work load. Significant HRs marked in boldface.

	LBP PINT		SP PINT	
	HR	**95%CI**	**HR**	**95%CI**
Work organization, job content				
Influence at work	1.46	0.86-2.46	1.43	0.83-2.46
Possibilities for development	0.99	0.53-1.84	1.07	0.54-2.11
Variation	0.97	0.53-1.79	0.89	0.47-1.69
Meaning of work	1.02	0.56-1.86	1.57	0.83-2.97
Commitment to the workplace	1.17	0.65-2.10	1.55	0.84-2.88
Interpersonal relations				
Predictability	1.59	0.88-2.88	1.70	0.91-3.17
Recognition	1.58	0.88-2.48	1.83	0.98-3.41
Role clarity	**2.07**	**1.08-3.95**	1.81	0.94-3.50
Role conflicts	1.17	0.61-2.24	1.76	0.88-3.53
Quality of leadership	1.76	0.91-3.42	0.98	0.50-1.95
Social support from colleagues	1.08	0.57-2.03	1.79	0.92-3.49
Social support from supervisors	1.24	0.67-2.28	0.96	0.51-1.80
Social community at work	1.61	0.89-2.93	**2.21**	**1.18-4.13**
Work organization	1.22	0.66-2.24	1.30	0.69-2.44
Interpersonal relations	**1.95**	**1.05-3.65**	**2.11**	**1.08-4.12**

Physical working conditions (Paper II)

The INC data demonstrated that the baggage handlers had their trunk flexed forward >60^o during 2% of their total working time (Table 6), with 71% of this time being spent in a neutral posture (<20^o) and a 90th percentile forward flexion of 34^o (Table 6).

On the average, the baggage handlers worked with their arms elevated >60^o (the right slightly more than the left) during 6% of their total working time, with the right and left arms in a neutral posture (<20^o) for 30% and 32% of this time, respectively (Table 6).

For the right and left arms, the 90th percentile elevation angle was 52^o and the 50th percentile movement velocity 11^{o}s^{-1}.

Both the trunk and arms exhibited more pronounced variability between subjects (SD_{BS}) than between days within subjects (SD_{BD}) (Table 6).

High exposure of the trunk (90^{th} and 99^{th} percentiles, duration of extreme postures, high velocity) and right arm (99^{th} percentile and time spent at >90^{o} elevation) to risk factors was greater among workers on the ramp than those in the sorting area.

Table 6. Trunk and upper arm postures and movements for 27 baggage handlers. Group mean values with standard deviations between subjects (SD_{BS}) and between days within subject (SD_{BD}). Results based on 79 full shifts. FP=Forward projection (trunk flexion in the sagittal plane), SP=Side-way projection (lateral flexion in the frontal plane). For SP, positive values denote bending to the right.

Exposure		Trunk		Upper arm	
		FP	SP	Right	Left
Posture					
10th percentile, °					
	Mean	-2.0	-8.5	12.3	11.9
	SD_{BS}	3.1	1.4	3.0	2.4
	SD_{BD}	3.5	1.7	3.0	3.7
50th percentile, °					
	Mean	10.2	0.6	28.2	27.3
	SD_{BS}	4.8	1.3	5.5	5.9
	SD_{BD}	3.9	1.1	4.6	4.9
90th percentile, °					
	Mean	34.1	9.4	51.8	52.0
	SD_{BS}	7.9	2.1	5.6	6.8
	SD_{BD}	4.8	1.9	4.7	5.2
99th percentile, °					
	Mean	69.7	23.3	89.3	85.4
	SD_{BS}	11.8	2.5	9.3	10.1
	SD_{BD}	9.1	3.1	6.7	6.1
Percentile range (10th-90th), °					
	Mean	36.1	17.9	39.5	40.0
	SD_{BS}	8.1	1.6	3.6	4.2
	SD_{BD}	5.1	2.0	4.4	5.5
Time in neutral (<20°), %					
	Mean	70.8	98.2	30.3	32.4
	SD_{BS}	10.3	0.7	11.6	12.9
	SD_{BD}	7.8	0.8	10.7	11.3
Time in extreme (>60°), %					
	Mean	2.1	0	6.4	6.3
	SD_{BS}	1.1	-	3.2	3.2
	SD_{BD}	1.1	-	1.8	2.4
Time in extreme (>90°), %					
	Mean	0.4	0	1.1	0.88
	SD_{BS}	0.3	-	0.59	0.49
	SD_{BD}	0.3	-	0.39	0.46
Frequency of 'periods (>3 s) in a neutral posture', min^{-1}	Mean	1.6	1.3	0.53	0.59
	SD_{BS}	0.30	0.34	0.41	0.44
	SD_{BD}	0.31	0.34	0.27	0.29

Movement velocity					
10th percentile, $°s^{-1}$					
	Mean	0.61	0.65	0.80	0.80
	SD_{BS}	0.43	0.45	0.57	0.58
	SD_{BD}	0.43	0.46	0.57	0.58
50th percentile, $°s^{-1}$					
	Mean	7.7	8.4	10.9	10.6
	SD_{BS}	1.4	1.6	2.4	2.6
	SD_{BD}	1.9	2.3	3.0	3.2
90th percentile, $°s^{-1}$					
	Mean	51.0	59.6	79.3	76.3
	SD_{BS}	6.4	6.9	10.9	11.4
	SD_{BD}	7.9	8.7	11.3	11.5
99th percentile, $°s^{-1}$					
	Mean	140.3	160.4	217.2	211.7
	SD_{BS}	18.4	16.0	26.8	29.8
	SD_{BD}	11.2	13.8	21.7	20.6
Time at low velocity (<5$°s^{-1}$ for >3 s), %	Mean	10.1	10.1	10.1	10.2
	SD_{BS}	7.8	7.8	7.8	7.7
	SD_{BD}	6.9	6.9	6.9	7.1
Time at high velocity (>90$°s^{-1}$) %	Mean	3.8	4.9	8.3	7.8
	SD_{BS}	1.1	1.1	1.8	1.8
	SD_{BD}	0.9	1.2	1.8	1.9
Posture and movement					
Time at rest (<20° AND <5$°s^{-1}$), %	Mean	31.2	41.2	15.7	16.6
	SD_{BS}	8.5	5.1	7.1	7.4
	SD_{BD}	6.4	6.1	7.6	7.7

Shoulder pain during work (Paper III)

The intensity of *daily pain* increased during approximately one-third of all shifts, more frequently for ramp than sorting work. Many baggage handlers experienced no pain, neither before nor after the work shift (38% and 42% absence of pain in the right and left arms, respectively). An additional 10% reported identical levels of pain before and after the shift, so that 50% of all shifts were associated with no change in pain in either shoulder.

The video-recordings revealed that handling aircraft constituted 48% of the ramp work. The mean number handled during a shift was 6 (range 2-12) and the mean time for handling 28 minutes (range 7-52).

On the average, sorting workers had lower ratings of pain both before and after work than ramp workers and a larger proportion of sorting shifts was associated with unchanged pain (p=0.04 and p=0.09 for the right and left shoulder, respectively).

Among ramp workers, *daily pain* in both the right and left shoulder was significantly associated with the number of *aircraft handled,* pain increased for each aircraft handled by 1.29 mm (95% CI 0.11-2.47) and 1.60 mm (0.44-2.76) for the right and left shoulders, respectively. Among sort workers, pain intensity increased by 0.55 mm (0.18-0.92) with each percent of time with *work in extreme* arm posture, but only for the right arm. This effect remained significant in a multivariate analysis including the psychosocial factors *influence* at work and *support* from colleagues. For sort workers, *daily pain* was associated with the duration of *time in extreme* postures, but this effect did not remain significant in a multivariate analysis (Table 7 and 8).

Implementation of an ergonomic intervention (Paper IV)

The implementation proved feasible with respect to three of the six evaluation variables, i.e., *dose delivered, dose received* and *satisfaction*. The intervention was delivered as originally planned and 60-86% of the participants rated themselves as engaged to a large extent, considered the knowledge to be useful, thought that they would get use for and practice their new knowledge, and were able and would have the opportunity to transfer this knowledge to colleagues. The participants were more satisfied with the time allocated to the Human Factor training (80%) than to the Ergonomics training (58%). Both were rated as relevant and satisfaction with the content was 88-91%.

The intermediate outcomes, confidence in using and talking about the loading devices, observed use of these devices by colleagues, and internal feedback on work behavior, all improved significantly ($p<0.01$).

The factors identified as facilitators of a successful implementation were all in the category of *trainee characteristics,* i.e., *self-efficacy, motivation, and perceived utility of training.*

The barriers belonged to the category of *work organization,* primarily *transfer climate*, lack of *training follow-up* and lack of explicit management policy and *support* regarding when and how to use loading assist devices. Since organisational changes, such as staff reduction, changes in work schedules and subsequent job insecurity were being carried out at the same time, the timing was another barrier.

Table 7. Univariate and multivariate associations between biomechanical and psychosocial factors and *daily pain* for the **right shoulder** for all shifts, and for ramp and sort shifts separately. (n(d): number of shifts; Coefficients significantly differing from 0 ($p<0.05$) are marked in bold).

		All		**Ramp**		**Sort**
Univariate	n(d)	B (95% CI)	n(d)	B (95% CI)	n(d)	B (95% CI)
Age	110	-0,09 (-0,27-0,08)	80	-0,02 (-3,33-10,30)	30	-0,28 (-0,63-0,07)
Shoulder pain before	112	**-0,24 (-0,41- -0,06)**	82	**-0,24 (-0,38- -0,10)**	30	-0,24 (-1,01-0,53)
Aircrafts handled	82	**1,29 (0,11-2,47)**	82	**1,29 (0,11-2,47)**		not included
Time in extreme	99	-0,03 (-0,25-0,19)	70	**-0,22 (-0,42- -0,03)**	29	**0,55 (0,18-0,92)**
Time in neutral	99	-0,22 (-0,57-0,12)	70	-0,25 (-0,75-0,25)	29	-0,15 (-0,44-0,14)
Influence	96	-0,08 (-0,26-0,09)	72	-0,20 (-0,45-0,04)	24	0,10 (-0,09-0,29)
Support	96	0,10 (-0,08-0,28)	72	0,14 (0,08-0,36)	24	-0,10 (-0,25-0,05)
Model 1						
Age			68	**0,21 (0,01-0,41)**	29	-0,04 (-0,26-0,18)
Shoulder pain before			68	**-0,32 (-0,48- -0,16)**	29	-0,17 (-0,86-0,51)
Aircrafts handled			68	**1,85 (0,44-3,25)**		not included
Time in extreme			68	-0,77 (-0,28-0,13)	29	**0,50 (0,15-0,85)**
Model 2						
Age			62	0,11 (-0,21-0,44)	23	**-0,99 (-1,38- -0,62)**
Shoulder pain before			62	**-0,24 (-0,40- -0,08)**	23	0,40 (-0,01-0,81)
Aircrafts handled			62	**1,74 (0,41-3,07)**		not included
Time in extreme			62	-0,29 (-0,63-0,05)	23	0,33 (-0,04-0,70)
Time in neutral			62	-0,43 (-0,94-0,09)	23	**-0,49 (-0,78- -0,20)**
Influence			62	**-0,45 (-0,83- -0,06)**	23	0,03 (-0,21-0,28)
Support			62	**0,33 (0,01-0,66)**	23	**-0,27 (-0,41- -0,14)**

Table 8. Univariate and multivariate associations between biomechanical and psychosocial factors and *daily pain* for the **left shoulder** for all shifts, and for ramp and sort shifts separately. (n(d): number of shifts; Coefficients significantly differing from 0 ($p<0.05$) are marked in bold).

	All		Ramp		Sort	
Univariate	n(d)	B (95% CI)	n(d)	B (95% CI)	n(d)	B (95% CI)
Age	109	-0,04 (-0,25-0,17)	80	-0,05 (-0,31-0,21)	29	0,20 (-0,16-0,55)
Shoulder pain before	111	**-0,33 (-0,55- -0,11)**	82	**-0,37 (-0,61- -0,12)**	29	-0,24 (-0,79-0,31)
Aircrafts handled	82	**1,60 (0,44-2,76)**	82	**1,60 (0,44-2,76)**		Not included
Time in extreme	98	-0,26 (-0,57-0,05)	70	**-0,28 (0,56-0,00)**	28	-0,30 (-1,27-0,67)
Time in neutral	98	-0,03 (-0,43-0,37)	70	-0,14 (-0,76-0,48)	28	0,18 (-0,18-0,54)
Influence	95	-0,08 (-0,25-0,09)	72	-0,20 (-0,47-0,07)	23	0,09 (-0,03-0,20)
Support	95	0,14 (-0,06-0,34)	72	0,20 (-0,05-0,44)	23	-0,11 (-0,24-0,02)
Model 1						
Age			68	0,00 (-0,20-0,20)	28	0,32 (-0,06-0,71)
Shoulder pain before			68	**-0,45 (-0,64- -0,27)**	28	**-0,34 (-0,66- -0,01)**
Aircrafts handled			68	**1,76 (0,50-3,03)**		not included
Time in extreme			68	0,09 (-0,17-0,35)	28	-0,16 (-0,70-1,02)
Model 2						
Age			62	-0,01 (-0,38-0,36)	22	**-0,42 (-0,65- -0,18)**
Shoulder pain before			62	**-0,44 (-0,64- -0,23)**	22	**0,28 (0,16-0,39)**
Aircrafts handled			62	**1,50 (0,40-2,60)**		not included
Time in extreme			62	-0,03 (-0,37- 0,32)	22	0,16 (-0,21-0,52)
Time in neutral			62	-0,11 (-0,74-0,52)	22	0,07 (-0,06-0,21)
Influence			62	**-0,46 (-0,82- -0,10)**	22	**0,12 (0,07-0,18)**
Support			62	**0,38 (0,03-0,72)**	22	**-0,09 (-0,14- -0,04)**

Discussion

A substantial number of the airline baggage handlers experienced pain in their lower back and shoulders, with LBP interfering with work to a greater extent than SP, and this pain was associated with psychosocial factors in the working environment.

The prevalence of low back (70%) and shoulder pain (60%) were higher than in the general population and indeed higher than those reported previously for workers performing manual handling, e.g., scaffolders (60% and 50%, respectively) [22], ambulance workers (60% and 46%) [1], and industrial workers (LBP 52%) [42]. Almost 20% and one-third of our workers reported that SP or LBP, respectively, interfered with their work, which was also more than reported for scaffolders (LBP 21%) and ambulance workers (LBP 23% and SP 7%). One possible explanation is that it may be easier to compensate for potentially dangerous postures in connection with ambulance work or engaging in tasks other than lifting and carrying equipment and patients.

Physical working conditions

The video recording in Study III revealed that baggage handlers spend 48% of their working shifts loading/unloading aircraft, driving vehicles, pushing/pulling baggage carts, directing aircraft and putting auxiliary power cables, brake bumpers and stairs into place, tasks assumed to involve heavy lifting as well as awkward postures and movements. Among Danish airline baggage handlers, more frequent MSDs reflected seniority [11] and an elevated incidence of shoulder disorders could be explained by cumulative years of employment [102].

The assessment of work postures and movements in Study II showed that the baggage handlers spent 6.4% of their working time with their arms in extreme postures (>60^o), a value lower than that reported for e.g., for car disassembly workers (15%) [50] and large-herd dairy parlor workers (17%) [21]. A reasonable hypothesis in this connection is that the active periods of aircraft handled are separated by periods of moderate activity or even rest. The 90^{th} percentile for arm posture was also lower in the case of baggage handlers (52^o) than car disassembly workers (72^o) and large-herd dairy parlor workers (72^{o}), but similar to several other service occupations, including material kitting (52^{o}) [15], dentistry (53^{o}) [43], cleaning (53^{o} -54^{o}) [105] and meat cutting (58^{o}) [5].

The peak movement velocity of baggage handlers (79^{o} s^{-1}) was moderate in comparison to that of cleaners (193^{o} s^{-1}) [105], large-herd dairy parlor workers (148^{o} s^{-1}) [21] , hairdressers (104^{o} s^{-1}) [107], car disassembly workers (101^{o} s^{-1}) [50] and poultry processing workers (98^{o} s^{-1}) [46]. The smaller arm angel and peak velocity of baggage handlers may reflect the force required to handle heavy bags.

The percentage duration of "extreme" trunk posture (>60^{o}) for baggage handlers was 2.1%. In prospective cohort studies, trunk flexion of more than 60^{o} for longer than 5% of the shift[37] and trunk flexion of more than 30^{o} for longer than 10% [39] were associated with an increased risk of LBP. Although the duration of 60^{o} trunk inclination was shorter, our 90th percentile trunk flexion was 34^{o} and baggage handlers probably performed more heavy lifting than the limit suggested by Hoogendoorn and co-workers (i.e., a maximum of 25 kg not more than 15 times during the shift) [37].

Ramp workers had more extreme postures and greater variation in trunk inclination than sort workers. This observation was confirmed by informal conversations with baggage handlers who claimed that sort work was physically easier. We could see ourselves that handling procedures in the sort area are not as severely constrained and can be adjusted to a greater extent than on the ramp and, in addition, more lifting aids were available for sorting. This may indicate that sort work is less physically demanding and that it is easier to remain being a sort worker, or you become a sort worker, with seniority as a baggage handler.

It would appear that, varying between ramp and sort work would be beneficial with respect to musculoskeletal disorders. The variation in work that reduces MSD optimally is not known at present [60, 63], but variation itself is necessary for a job to be considered ergonomically acceptable [66].

Baggage handling appears to involve periods with activities that demand more force and in study III, the number of aircraft handled was associated with pain. Pain increased in approximately one-third of all the shifts measured, less in the case of sort. This increase was only 2.5 mm and 1.9 mm for right and left shoulder, respectively, but no other report of associations between daily pain and daily exposure to risk factors in a comparable population could be found. Andersen and colleagues [4] found that low back pain among workers at supermarkets was increased by 0.55 units on a (0-10 scale) on the morning after a after a workday and moreover, consecutive workdays exerted a cumulative impact on pain. Despite the study differences, while that study addressed low-back pain and found a more pronounced effect, we believe our results to be in the same direction.

Psychosocial working conditions

In addition to the physically strenuous tasks involved in airline baggage handling, we found dissatisfaction with psychosocial factors, i.e., personal relations, leadership, support, influence and the organization of work (Paper I). Shoulder pain that interfered with work demonstrated a particularly strong association with social support from colleagues, in agreement with the conclusions of several reviews [35, 37, 124]. Low back complaints and limitation of activity were also associated with social support from colleagues and supervisors.

One interpretation of these findings is that support from colleagues may enable the worker, despite pain, to plan and perform tasks in an efficient manner with reduced physical effort. In contrast, lack of support or influence may give rise to pressure and stress and thereby contribute to elevated muscle tension, blood and metabolic disturbances, and a subsequently enhanced risk of developing or further aggravating pain [65]. This proposal corresponds to the claim by Woods [124] that lack of social support is associated with restricted activity and absenteeism, as well as lower probability of returning to work.

Implementation of an ergonomic intervention

The intervention was delivered as planned and satisfaction among the participants was high. However, the training did not lead to the desired general improvement in work performance by the baggage handlers.

The positive effects on the intermediate outcomes, with changes in the confidence and work behavior of the key individuals who participated may have been due to and facilitated by the characteristics of these individuals, the recruited trainees. Although the recruitment was not successful in terms of reach, the recruitment of dedicated and motivated trainees was a particularly important facilitator. Their key roles in the company may have enhanced their motivation to learn and practice new skills, as well as their perception of the utility of training. Indeed, previous studies indicate that with strong motivation trainees high self-efficacy [113] and previous experience of tools and ergonomic advantage of using devices [112] are prerequisite for effective transfer of trained skills to the worksite [27]. Recruiting the right team members, workers, supervisors and specialists with the appropriate skills and knowledge and representing larger groups at the worksite appears to be effective [109].

The desired increase in the use of loading assist devices was not observed, according to participants because of a lack of manager support and time for practicing in realistic situations and problem solving. The importance of practice and extended periods of training for improving skills has been emphasized in the literature. Training attendance and eventual behavioral effects are facilitated if managers also undergo training and use rewards and sanctions in the work environment [98]. However, the lack of belief in the utility of training among our managers was verified in interviews. They were not convinced that more training would increase the use of devices and argued that the alleged time constraint for practice reflected priorities, rather than being a barrier in itself.

One of the major barriers here was the lack of “visible leadership”, i.e., manager support in connection with providing feedback to workers who break the rules concerning the use of loading devices. Visible leadership is key to the promotion of productivity and good health in an organization [58]. Better integration of managers is vital to the success of future interventions designed to improve baggage handling.

Another barrier related to the present training design was a lack of follow-up. Organizational restructuring and staff reduction, previously reported to be important in this context [73], were barriers beyond the control of the implementer.

Potential confounders

Data on the potential confounders age, BMI, general health and physical work load were collected and these were controlled for in the analyses of Study I. Since only 2% of the participants were women, gender was not controlled for. Leisure-time physical activity may act as a confounder in a study like ours and we did not collect any information about this.

The conclusion in Study III that the number of aircraft handled is associated with daily shoulder pain, assumes that exposure to risk factors is similar at different airports, even if we suspect that this is not the case. However, stratified analyses designed to control for potential confounding factors such as differences in types of aircraft, availability of loading devices and the amount of baggage checked in were not possible because of the low number of measurements performed at all the airports except one.

Methodological considerations

Since a cross-sectional design was used in Study I, the relationship presented must be interpreted with great caution. No conclusions concerning causality can be drawn because of the difficulties involved in determining temporal relationships between exposure and outcome when all data are collected at the same time [6].

The response rate in Study I was 65%, which is considered acceptable for minimizing the risk of selection bias. At the same time, we did not have any information about the non-participants and could therefore not compare them to the participants. Pain could have been a motivating factor for participation and, indeed, with such studies non-participants typically experience less pain than participants [80]. On the other hand, employees on sick leave did not participate, which may have led to an underrepresentation of pain in our results.

The baggage handlers in Study I were compared to the general population, which includes both healthy and unhealthy individuals. Since this occupation requires good physical condition workers who develop MSDs may quit, leading to so called “healthy worker effect” and an underestimated risk of developing MSDs. However, in light of the considerable prevalence of MSDs in our study, this does not appear to be the case here. Furthermore, the annual turnover of the workforce in the companies participating was reported to be less than 5%.

In attempt to maximize participation baggage handlers were asked to complete the questionnaires at work. We acknowledge the attributable risk involved here, i.e., the risk of overestimating the prevalence and intensity of pain, as well as the perception of pain interfering with work [17].

Job titles are often used to describe occupations. In Studies II and III we described baggage handling with good internal validity on the basis of objective measurements of biomechanical exposure, video recordings and diaries documenting work tasks performed on the same day. In Study III pain intensity was assessed immediately before and after the shift being measured, thereby eliminating the risk of recall bias.

Postural inclination was measured relative to gravity, so that inclination of the arm in relationship to the trunk was not determined. One limitation of this standard approach is that it does not discriminate between elevation in the frontal and sagittal planes. Furthermore, shoulder elevation is dependent on trunk posture, so with the trunk bending forward, arm elevation appears to be lower relative to the line of gravity.

We were not allowed to analyze the occurrence of heavy manual handling involving awkward postures and movements, which is likely to constitute a particular risk with respect to MSDs, especially for the low back [92]. Estimating muscle force during heavy loading by electromyography (EMG) [103], would have been interesting but was unfortunately, not feasible.

Our process evaluation focused on factors that influence intervention implementation under realistic less-than-ideal circumstances [55]. Extensive information was collected systematically and the approach to barriers and facilitators was based on a theoretical framework, which has been lacking in much previous research on implementation [83, 117]. Comparison to a reference organization would have been desirable, but was not possible in this case. The changes in the intermediate outcomes observed should therefore be interpreted with caution.

Conclusions

Although our study designs do not permit conclusions regarding causal relationships, our findings indicate that dissatisfaction with psychosocial factors, along with awkward working postures may partially explain pain in baggage handlers.

The prevalence of LBP and SP among baggage handlers was high, 70% and 60%, respectively, with 45% of workers experiencing both forms of pain. LBP interfered with work (30%) to a greater extent than shoulder pain (18%). Dissatisfaction was highest with the quality of leadership and lack of influence at work, while baggage handlers were most satisfied with their social community at work. Intense pain and pain that interfered with work were associated with psychosocial factors related to work organization, job content, interpersonal relations and leadership.

Extreme postures with arms elevated >60° occurred for 6.4% of the total time, and in trunk flexion >60° for 2.1% of the total time. In contrast, 71% of time was spent in a neutral trunk posture. The 90th percentile trunk forward flexion was 34.1°. The duration of time spent in peak (>90°) upper arm elevation and trunk FP angles was higher in ramp than sort workers. Both the trunk and arms exhibited more pronounced variability between subjects (SD_{BS}) than within subjects between days (SD_{BD}).

Daily shoulder pain increased during approximately one-third of all shifts and was significantly associated with the number of aircraft handled for ramp workers, and with time in extreme postures for sort workers; in both cases, SP was modified by influence and support.

The program implementation proved feasible with respect to the dose delivered, dose received and satisfaction. Participants confidence increased concerning the use of - and talk about - loading devices, observed use of these devices by colleagues, and feedback about work behavior. One important implementation facilitator was motivated trainees, while barriers included lack of manager support, opportunities to observe and practice, and follow-up activities, as well as staff reduction and job insecurity.

Future perspectives

Variation in biomechanical exposure is important for minimizing the risk of developing musculoskeletal disorders. Knowledge on specific exposure data occurring during the different work tasks comprising aircraft handling would help prioritize required interventions and design effective interventions aimed at preventing musculoskeletal disorders and promoting good health. Furthermore, this knowledge would permit the design of appropriate job rotation strategies to introduce exposure variation throughout the work day resulting in altered temporal loading patterns and the possibility to change individual workloads. This variation in work could not only prevent workers from developing MSDs, but also reduce early retirement due to MSDs.

Work exposure varies across time, as does individual discomfort and pain. To understand how biomechanical exposure modulates pain, data on changes in exposure and in pain are required at more regular intervals than have been collected to date (ex. every 1 – 2 years), and over longer time periods than in our study III, which measured on only one day. Such data would enable analyses of determinants for the incidence of musculoskeletal disorders and also the consideration of chronic pain.

The process of transferring research findings into practice needs to be more effective than current practice. Implementation challenges can be better overcome and intervention effectiveness can be increased with a better understanding of the process. Future dissemination and implementation research should aim at determining and investigating factors that influence the extent to which implementation of interventions occurs in different organizations and how these factors influence adoption of the intervention. There is also a need to understand organizational readiness for change and the impact that will have on implementation and intervention success.

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Sammanfattning på svenska

Att lasta flygplan anses vara ett tungt manuellt arbete med en ökad risk att drabbas av belastningsrelaterade besvär till följd av ogynnsamma arbetsställningar och tung manuell hantering. Inom Transportfacken har man registrerat en ökning av besvär, men samtidigt haft svårigheter att driva sjukpenning- och arbetsskadeärenden på grund av att kunskapen om arbetet och dess belastningar är relativt okända. Ett projekt inleddes för att kartlägga, förebygga och minska riskerna för belastningsrelaterade besvär.

Syftet med den här avhandlingen var att undersöka förekomsten av ländryggs- och axelbesvär samt den fysiska och psykosociala arbetsmiljöns betydelse för risken att drabbas av besvär. Syftet var också att utvärdera implementeringen av en ergonomisk intervention, baserad på resultat som ingår i avhandlingen, som syftade till att öka användningen av arbetsredskap.

Ett frågeformulär besvarades av 525 flygplanslastare på sex flygplatser och användes för att studera smärta och psykosociala faktorer. Arbetsställningar för rygg och armar mättes med inklinometer på 55 personer under 114 hela arbetsskift. Före och efter skiftet skattades ländryggs och axelsmärta och under skiftet noterade lastarna antalet flygplan som lastades respektive lossades i en dagbok. Samband mellan biomekaniska och psykosociala arbetsmiljö faktorer och smärta analyserades och implementeringen av den ergonomiska interventionen utvärderades med hjälp av enkäter och upprepade intervjuer.

Förekomsten av ländryggs- och axelbesvär var hög, 70% respektive 60% och smärta som påverkade arbetet förekom i större utsträckning för rygg (30%) än för axlar (18%). Av de psykosociala faktorerna var man mest missnöjd med ledarskap och inflytande och mest nöjd med kamratskapen på arbetsplatsen och det fanns signifikanta samband mellan besvär som påverkade arbetet och missnöje med den psykosociala arbetsmiljön. Extrema arbetsställningar, det vill säga arbete med armarna över 60^{o} förekom under 6.4% av arbetstiden och med framåtböjd rygg mer än 60^{o} under 2.1% av arbetstiden. Tiden för arbete i extrema arbetsställningar för rygg och armar var något längre för de som arbetade med att lasta/lossa flygplan på rampen än för de som arbetade i bagagesorteringen. Under en tredjedel av arbetsskiften ökade axelsmärtan och det fanns ett positivt samband mellan ökad smärta och antalet flygplan som lastades/lossades under ett skift och arbete med armar i extrema arbetsställningar. Smärtan modifierades även av inflytande och kollegialt stöd på arbetsplatsen.

Flygplanslastarnas arbetsställningar var i nivå med andra yrkesgrupper inom manuell hantering som anses ha en ökad risk för belastningsrelaterade besvär. Våra resultat indikerar att såväl fysiska som psykosociala faktorer i arbetet är viktiga att ta hänsyn till vid planering och genomförande av interventioner för att minska och förebygga belastningsbesvär i den här branschen.

Utvärdering av implementeringen av interventionen visade att deltagarna var nöjda med innehåll och upplägg. De upplevde ökat självförtroende och ökad kunskap vad gäller användning och instruktion av arbetsredskap till kollegor samt en kortsiktig generell ökning av användningen. Målsättningen att öka användningen av arbetsredskap på lång sikt kunde dock inte observeras. Implementeringsfaktorer som var faciliterande var att rekrytera motiverade nyckelpersoner i organisationen medan hinder var upplevelsen av ett bristande ledarskap med en oklar policy vad gäller användningen av arbetsredskap. Stöd för att öva och lära under arbetstid samt uppföljning av interventionen saknades också. Tidpunkten visade sig vara dålig då organisatoriska förändringar som varsel av personal, förändringar i hur arbetet organiseras och en allmänt upplevd arbetsoro uppstod och hade varit svåra att förutspå.

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